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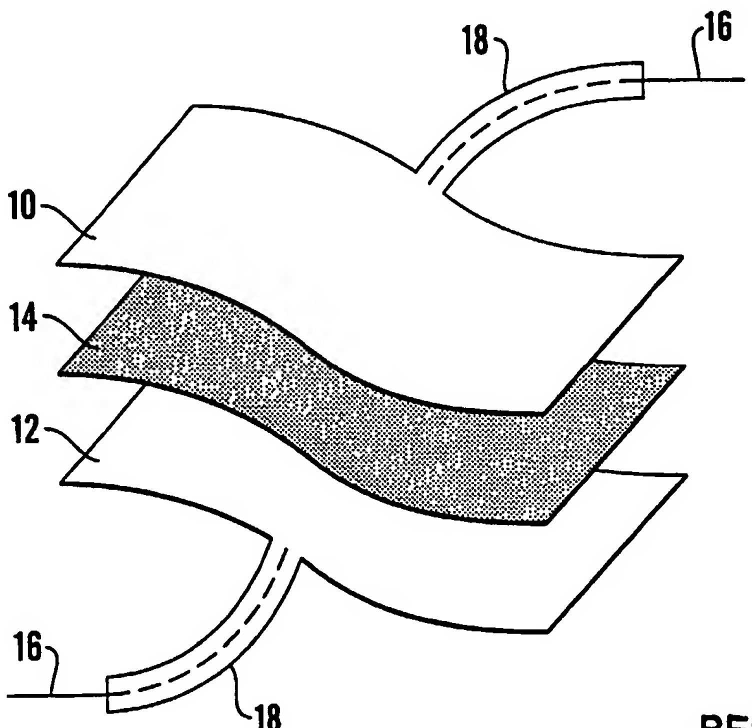
(54) Title: FLEXIBLE SWITCHING DEVICES



(57) Abstract: An electronic resistor user interface comprises flexible conductive materials and a flexible variably resistive element capable of exhibiting a change in electrical resistance on mechanical deformation and is characterised by textile-form electrodes (10,12), a textile form variably resistive element (14) and textile-form members (16) connective to external circuitry.

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FLEXIBLE SWITCHING DEVICES

TECHNICAL FIELD

This invention relates to electrical switching devices and more particularly to the architecture and construction of flexible switching devices and the use thereof in switching and proportional control of electric/electronic currents.

The working components of these devices can appear as and perform similarly to conventional textile materials and thus have applications as user-interfaces (including pressure sensors) particularly in the field of textile/wearable electronics. The devices are applicable as alternatives to 'hard' electronic user-interfaces. Generally the devices can be produced using commercial textile manufacturing processes but the invention is not limited to such processes.

In this specification:

'textile' includes any assemblage of fibres, including spun, monofil and multifilament, for example woven, non-woven, felted or tufted; and the fibres present may be natural, semi-synthetic, synthetic, blends thereof and metals and alloys;

'electronic' includes 'low' currents as in electronic circuits and 'high' currents as in circuits commonly referred as 'electric';

'user interface' includes any system in which a mechanical action is registered as a change in electrical resistance or conductance. The mechanical action may be for example conscious bodily action such as finger pressure or footfall, animal movement, pathological bodily movement, expansion or contraction due to bodily or inanimate temperature variation, displacement in civil engineering structures.

'mechanical deformation' includes pressure, stretching and bending and combinations of these.

SUMMARY OF THE INVENTION

The invention provides an electronic resistor user-interface comprising flexible conductive materials and a flexible variable resistive element capable of exhibiting a change in electrical resistance on mechanical deformation, characterised by textile-form electrodes, a textile-form variably resistive element and textile-form members connective to external circuitry.

It will be appreciated that the textile form of each component of the user-interface may be provided individually or by sharing with a neighbouring component.

The electrodes, providing a conductive pathway to and from either side of the variably resistive element, generally conductive fabrics (these may be knitted, woven or non-woven), yarns, fibres, coated fabrics or printed

fabrics or printed fabrics, composed wholly or partly of conductive materials such as metals, metal oxides, or semi-conductive materials such as conductive polymers (polyaniline, polypyrrole and polythiophenes) or carbon. Materials used for coating or printing conductive layers onto fabrics may include inks or polymers containing metals, metal oxides or semi-conductive materials such as conductive polymers or carbon. Preferred electrodes comprise stainless steel fibres, monofil and multifilament or stable conducting polymers, to provide durability under textile cleaning conditions.

The electrodes can be supported by non-conducting textile, preferably of area extending outside that of the electrodes, to support also connective members to be described.

Methods to produce the required electrical contact of the electrode with the variably resistive element include one or more of the following:

a) conductive yarns may be woven, knitted, embroidered in selected areas of the support so as to produce conductive pathways or isolated conductive regions or circuits;

b) conductive fabrics may be sewn or bonded onto the support;

c) conductive coatings or printing inks may be laid down onto the support by techniques such as spraying, screen printing, digital printing, direct coating, transfer coating, sputter coating, vapour phase deposition, powder coating and surface polymerisation.

Printing is preferred, if appropriate using techniques such as resist, to produce contact patterns at many levels of complexity and for repetition manufacture.

The extension of the support outside the electrode region is sufficient to accommodate the connective members to be described. It may be relatively small, to give a unit complete in itself and applicable to a user-apparatus such as a garment.

Alternatively it may be part of a user-apparatus, the electrodes and variably resistive element being assembled in situ. It may carry terminals at which the connective members pass the electric current to other conductors.

The variably resistive element, providing a controllable conductive pathway between the two electrodes, may take a number of forms, for example

a) a self-supporting layer;

b) a layer containing continuous or long-staple textile reinforcement;

c) a coating applied to the surface of textile eg. as fabrics, yarns or fibres. This coating preferably contains a particulate variably resistive material as described in PCT/GB99/00205, and may contain a polymer binder such as polyurethane, PVC, polyacrylonitrile, silicone, or other elastomer. Alternatively the variably resistive material may be for example a metal oxide, a conductive polymer (such as polyaniline, polypyrrole and polythiophenes) or carbon. This coating may be applied for example by commercial methods such as direct coating, transfer coating, printing, padding or spraying;

d) it may contain fibres that are inherently electrically conductive or are extruded to contain a variably resistive material as described in PCT/GB99/00205;

e) it may be incorporated into or coated onto one of the electrodes in order to simplify manufacturing processes or increase durability in certain cases.

The variable resistor generally comprises a polymer and a particulate electrically conductive material. That material may be present in one or more of the following states:

a) a constituent of the base structure of the element;

b) particles trapped in interstices and/or adhering to surfaces;

c) a surface phase formed by interaction of conductive particles (i or ii below) with the base structure of the element or a coating thereon.

Whichever state the conductive material of the variably resistive element is present in, it may be introduced:

i) 'naked', that is, without pre-coat but possibly carrying on its surface the residue of a surface phase in equilibrium with its storage atmosphere or formed during incorporation into the element. This is clearly practicable for states a) and c), but possibly leads to a less physically stable element in stage b);

ii) lightly coated, that is, carrying a thin coating of a passivating or water-displacing material or the residue of such coating formed during incorporation into the element. This is similar to i) but may afford better controllability in manufacture;

iii) polymer-coated but conductive when undeformed. This is exemplified by granular nickel/polymer

compositions of so high nickel content that the physical properties of the polymer are weakly if at all discernible. As an example, for nickel starting particles of bulk density 0.85 to 0.95 this corresponds to a nickel/silicone volume ratio (tapped bulk:voidless solid) typically over about 100. Material of form iii) can be applied in aqueous suspension. The polymer may or may not be an elastomer. Form iii) also affords better controllability in manufacture than i).

iv) Polymer-coated but conductive only when deformed. This is exemplified by nickel/polymer compositions of nickel content lower than for iii), low enough for physical properties of the polymer to be discernible, and high enough that during mixing the nickel particles and liquid form polymer become resolved into granules rather than forming a bulk phase. This is preferred for b) an may be unnecessary for a) and c). It is preferred for the present invention: more details are given in co-pending application PCT/GB99/00205. An alternative would be to use particles made by comminuting materials as in v) below. Unlike i) to iii), material iv) can afford a response to deformation within each individual granule as well as between

granules, but ground material v) is less sensitive. In making the element, material iv) can be applied in aqueous suspension;

v) Embedded in bulk phase polymer. This relates to a) and c) only. There is response to deformation within the bulk phase as well as between textile fibres.

The general definition of the preferred variably resistive material exemplified by iv) and v) above is that it exhibits quantum tunnelling conductance ('QTC') when deformed. This is a property of polymer compositions in which a filler selected from powder-form metals or alloys, electrically conductive oxides of said elements and alloys, and mixtures thereof are in admixture with a non-conductive elastomer, having been mixed in a controlled manner whereby the filler is dispersed within the elastomer and remains structurally intact and the voids present in the starting filler powder become infilled with elastomer and particles of filler become set in close proximity during curing of the elastomer.

The connective textile member providing a highly flexible and durable electrically conductive pathway to and from each electrode may for example comprise conductive tracks in the non-conducting textile support

fabric, ribbon or tape. The conductive tracks may be formed using electrically conductive yarns which may be woven, knitted, sewn or embroidered onto or into the non-conducting textile support. As in the construction of the electrodes, stainless steel fibres, monofil and multifilament are convenient as conductive yarns. The conductive tracks may also be printed onto the non-conducting textile support. In certain cases the conductive tracks may need to be insulated to avoid short circuits and this can be achieved by for example coating with a flexible polymer, encapsulating in a non-conducting textile cover or isolating during the weaving process. Alternatively the yarns may be spun with a conductive core and non-conducting outer sheath. In another alternative at least one connective member comprises variably resistive material pre-stressed to conductance, as described in PCT/GB99/02402.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 shows a basic switch;

Fig. 2 shows a switch adaptable to multiple external circuits;

Fig. 3 shows a multiple key device; and

Fig. 4 shows a position-sensitive switch.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In conjunction with appropriate electronics the devices may be used for digital type switching, analogue switching, proportional control, pressure sensing, flex sensing in the following applications, for example:

interfaces to electronic apparatus such as:

computers, PDA, personal audio, GPS;

domestic appliances, TV/video, computer games, electronic musical instruments, toys lighting and heating, clocks and watches;

personal healthcare such as heart rate monitors, disability and mobility aids;

automotive user controls;

controls for wearable electronics;

educational aids;

medical applications such as pressure sensitive bandages, dressings, garments, bed pads, sports braces;

sport applications such as show sensors, sensors in contact sport (martial arts, boxing, fencing), body armour that can detect and measure hits, blows or strikes, movement detection and measurement in sports garments;

seat sensors in any seating application for example auditoria and waiting rooms;

garment and shoe fitting;

presence sensors, for example under-carpet, in-flooring and in wall coverings.

Referring to Fig. 1, the basic textile switch/sensor device comprises two self-supporting textile electrodes 10,12 sandwiching variably resistive element 14 made by applying to nylon cloth an aqueous suspension of highly void-bearing granular nickel-in-silicone at volume ratio within the composition of 70:1 capable of quantum tunnelling conduction, as described in PCT/GB99/00205. Electrodes 10,12 and element 14 are fixed in intimate contact so as to appear and function as one textile layer. Each electrode 10,12 is conductively linked to a connective textile element 16 consisting of stainless steel thread in nylon tape 18 extending from electrodes 10,12. When pressure is applied to any area of electrode 10,12 the resistance between them decreases. The resistance between electrodes 10,12 will also decrease by bending.

Referring to Fig. 2, in a variant of the basic textile switch/sensor, upper layer 20 is a non-conducting textile support under which adheres the upper electrode constituted by discrete electrically conductive sub-area 22 conductively linked to connective member 24, which is a conductive track in extension 26 of support 20. Variably resistive element 28, similar to that of element 12 above but containing polyurethane binder, is provided as a

coating on lower electrode 29, the area of which is greater than that of upper electrode 22. Lower electrode 29 is formed with lower connective member 24, a conductive track on an extension 26 of electrode 29. When pressure is applied to sub-are a 22, the resistance between elements 22 and 29 changes. Effectively this defines a single switching or pressure sensitive area 22 in upper layer 20.

Referring to Fig. 3, a multiple key textile switch/sensor device is similar in form to that shown in Fig. 2 except that under upper layer 30 are adhered three discrete electrodes constituted by electrically conductive sub-areas 32,34 and 36 isolated from each other by the non-conducting textile support and electrically linkable to external circuitry by way of connective members 33,35,37 respectively, which are conductive tracks on extension 31 of layer 30. Variably resistive element 38 is provided as a coating on lower electrode 39; it is of the type <u>decreasing</u> in resistance when mechanically deformed, since it depends on low or zero conductivity in the plane of element 38. Electrical connection to lower electrode 39 is by means of conductor 24 and extension 26, as in Fig. 2. When pressure is applied to any of areas overlying electrodes 32,34 and 36, the resistance between the relevant electrode(s) and lower electrode 39 decreases. Effectively this defines three separate switching or

pressure sensitive areas 32,34 and 36, suitable as individual keys in a textile keypad or individual pressure sensors in a textile sensor pad. If the sensor is to respond to bending, other electrodes in contact with lower layer 39 would be provided to measure changes in conductivity in the plane of that layer; at the same time the external circuit would temporarily switch out the measurement perpendicular to the plane of layer 39.

Referring to Fig. 4, in a matrix switch/sensor device the upper layer 40 and lower layer 42 each contains parallel linear electrodes consisting of isolated rows 44 and columns 46 of conductive areas woven into a non-conducting textile support. Conductive areas 44, 46 are warp yarns that have been woven between non-conductive yarns. Variably resistive element 48 is a sheet of fabric carrying nickel/silicone QTC granules as in Fig. 1 applied by padding with an aqueous dispersion of the granules, which are of the type <u>decreasing</u> in resistance on mechanical deformation. Layer 48 is supported between layers 40 and 42 and coincides in area with electrodes 44 and 46. When pressure is applied to a localised area of 40 or 42 there is a decrease in resistance at the junctions of the conductive rows 44 and columns 46 which fall within the localised area of applied pressure. This device can be used as a pressure map to locate force applied within the

area of the textile electrodes. By defining areas of the textile electrodes as keys, this device can also be used as a multi-key keypad.

Example.

One electrode is a fabric consisting of a 20g/m2 knitted mesh containing metallised nylon yarns. The variably resistive element was applied to this fabric by transfer coating of:

75% w/w water based polyurethane (Impranil-Dow chemical); and

27% w/w nickel/silicone QTC granules (size 45-70micrometres)

and was cured on the fabric at 110C. The other textile electrode element is another piece of the same knitted mesh. Each electrode was then sewn onto a non-conducting support fabric sheet of greater area than the electrode. The sensor was assembled with the coated side of the first electrode element facing the second electrode. Separate connective textile elements each consisting of metallised nylon thread were sewn up to each electrode so that good electrical contact was made with each. On the non-conducting support fabric outside the electrodes two metal textile press-studs were fixed such that each was in contact with the two conductive yarn tails. An electrical

circuit was then connected to the press-studs so that a sensor circuit was completed.

CLAIMS

1. An electronic resistor user-interface comprising flexible conductive materials and a flexible variably resistive element capable of exhibiting a change in electrical resistance on mechanical deformation, characterised by textile-form electrodes, a textile-form variably resistive element and textile-form members connective to external circuitry.

2. A user-interface according to claim 1 in which at least one electrode is supported on non-conducting textile as conductive yarn woven, knitted or embroidered into the support, as conductive fabric sewn or bonded onto the support or as conductive coating applied to the support.

3. A user-interface according to claim 1 in which at least one electrode is formed by applying a conductive printing ink to the support textile.

4. A user-interface according to any one of the preceding claims in which the variably resistive element is formed as a coating applied to textile and consisting of particulate variably resistive material and an elastomer binder.

5. A user-interface according to any one of the preceding claims in which the variably resistive material exhibits quantum tunnelling conduction when deformed.

6. A user-interface according to claim 5 in which the variably resistive material is a polymer composition in which a filler selected from powder-form metallic elements or alloys, electrically conductive oxides of said elements and alloys, and mixtures thereof, are in admixture with a non-conductive elastomer, having been mixed in a controlled manner whereby the filler is dispersed within the elastomer and remains structurally intact and the voids present in the starting filler powder become infilled with elastomer and particles of filler become set in close proximity during curing of the elastomer.

7. A user-interface according to any one of the preceding claims in which at least one support textile is formed with a sub-area extending outside the area of the electrode.

8. A user-interface according to claim 7 in which the extension supports the connective member(s).

9. A user-interface according to any one of the preceding claims in which the connective members are constituted by conductive material present as conductive tracks in the textile support and/or in ribbon or tape.

10. A user-interface as claimed in claim 9 in which the tracks are woven, knitted, sewn or embroidered into or onto the support, ribbon or tape.

11. A user-interface according to claim 9 in which the conductive track(s) are printed onto the support textile.

12. A user-interface according to any one of the preceding claims in which at least one electrode and/or connective member comprises variably resistive material pre-stressed to conductance.

13. A user-interface according to any one of the preceding claims in which the extension of the support outside each electrode carries a terminal at which a connective member passes electric current to other conductors.

14. A user-interface according to any one of the preceding claims in which at least one electrode and/or connective member comprises stainless steel fibres and/or monofil and/or multifilament.

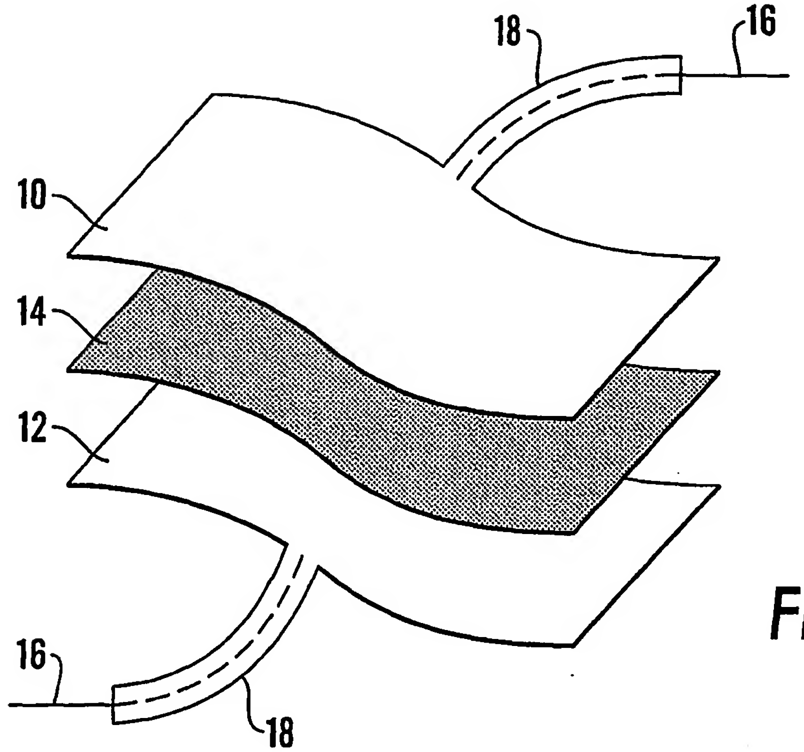

Fig. 1

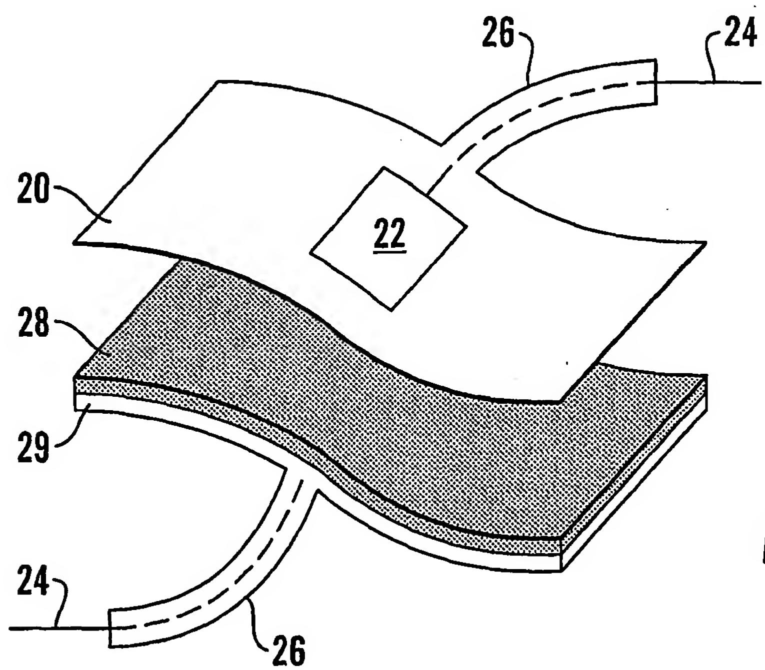

Fig. 2

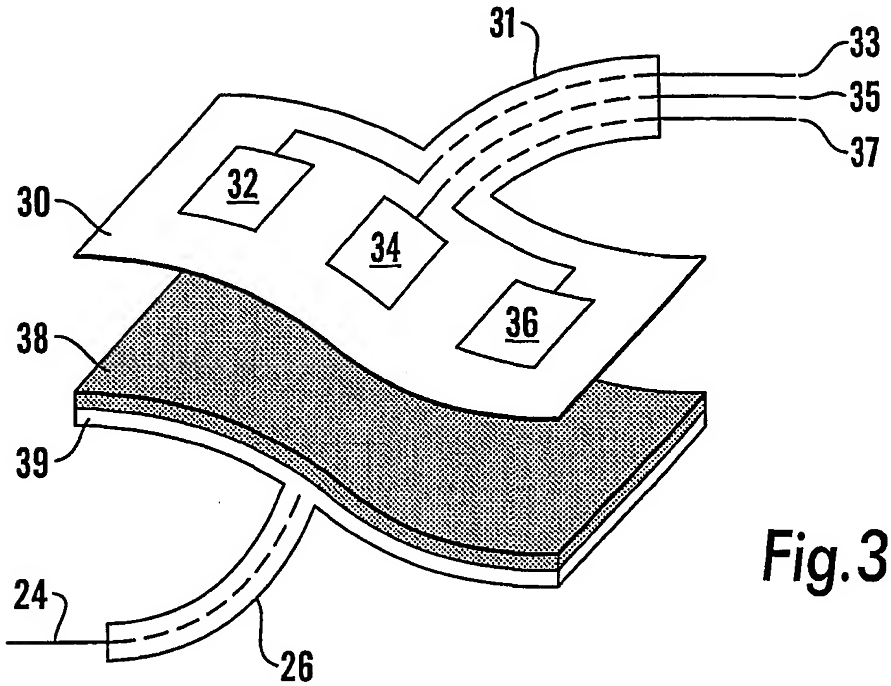

Fig.3

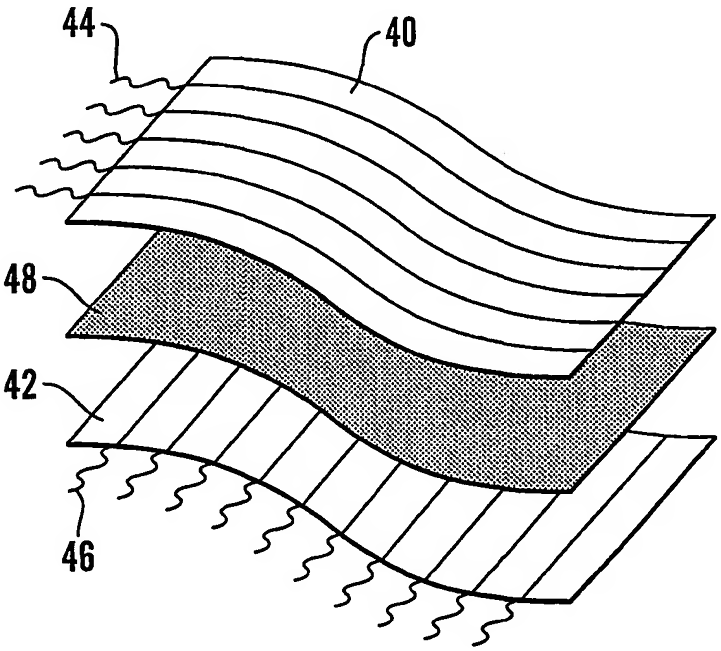

Fig.4

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INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01H3/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2 343 516 A (UNIV BRUNEL) 10 May 2000 (2000-05-10) abstract; figure 1	1
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A	DE 38 05 887 C (KROMBERG&SCHUBERT) 21 September 1989 (1989-09-21) abstract; figures	1

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
20 August 2001	28/08/2001

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INTERNATIONAL SEARCH REPORT

International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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